R-matrix calculations for Nuclear Data Evaluation with GECCCOS

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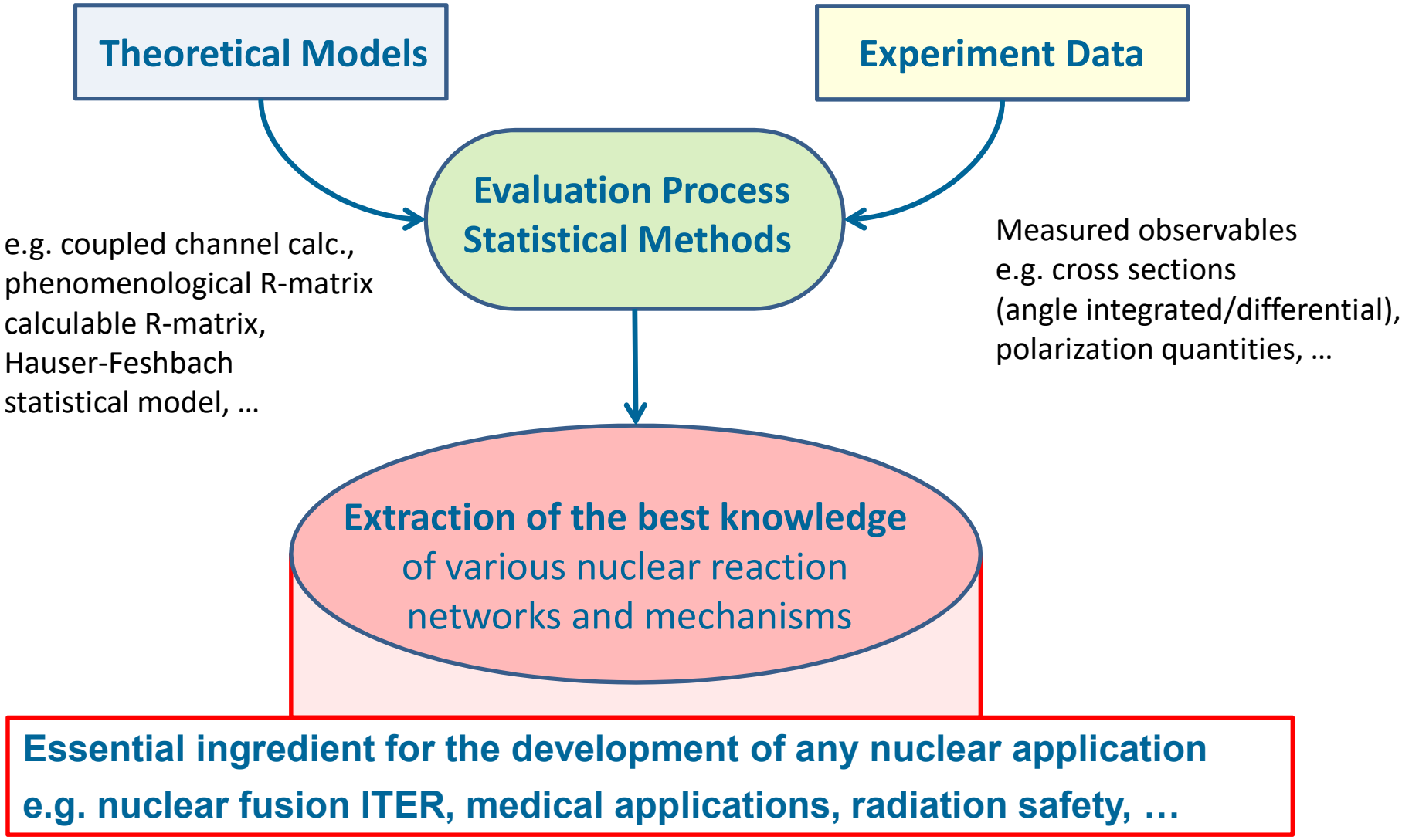
Nuclear Data Evaluation

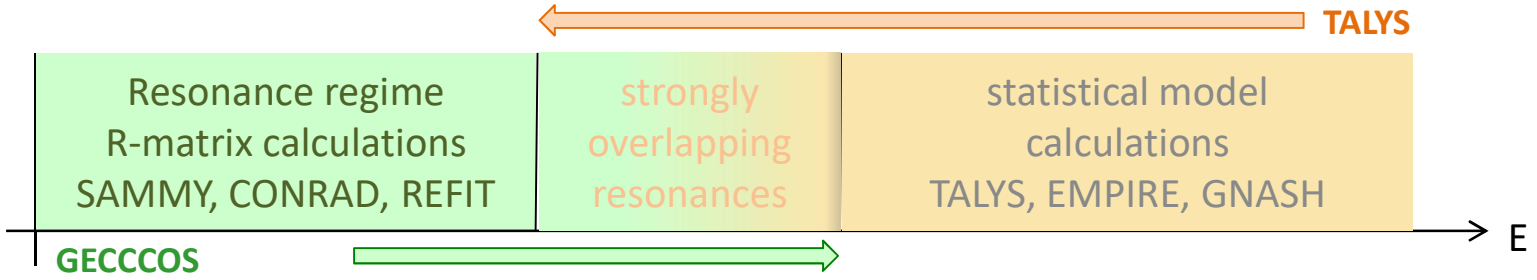


Nuclear Data Evaluation

Various methods in use for different nuclei and energy regions

Special challenges for light nuclei:

- ***Challenge of light nuclear systems:*** reactions of light nuclear systems exhibit resonant behaviour up to high energies
- ***Missing microscopic basis:*** in the absence of a proper theory of resonances, phenomenological R-matrix fits to experimental cross section data are usually performed at the cost of losing predictive power. Restriction to two-body channels.
- ***Problem of consistency:*** calculations in the resonance region (R-matrix) and at higher energies must show a smooth transition but are based on completely different concepts;



Goal: Development of an R-matrix based method to gain a **continuous transition** between the resonance regime and standard reaction calculations (statistical model and coupled-channel)

Why develop from scratch?

Key benefit:

knowledge about implementation details is instantly available

- Designed to be a versatile platform to test and develop new evaluation methods or extend existing ones
- → **Study different aspects of calculable and phenomenological R-matrix**

Final goal: create a reference implementation of a method that guarantees a smooth transition from resonance region to statistical model regime

→Output Compatibility with TALYS

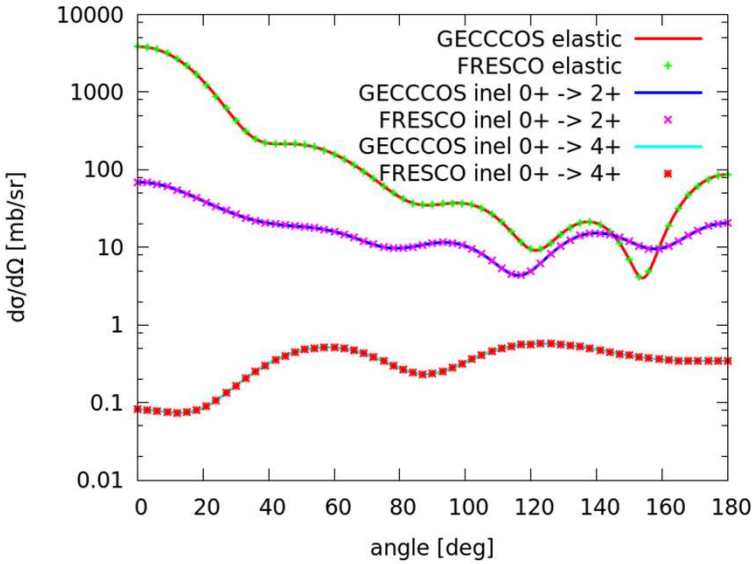
→ENDF-File generation via TEFAL-Code → ACE-Files → Application Simulation

Implemented Routines

- **Calculable R-matrix via Lagrange-mesh technique**
  by P. Descouvemont and D. Baye, Rep. Prog. Phys. 73, 036301 (2010)
- **Phenomenological R-matrix:**
  standard options for a_c, B_c available
- **Hybrid approach**
  background via potential, resonances phenomenological
- **Transformation of the matching radius**
- **Reduced R-matrix** (T. Stary [Master Thesis])
  Introduced by A.M. Lane, R.G. Thomas in Ref. Modern Physics 30 (1958) 257 chapter10
  Restricts dimension of R-Matrix to included channel subset
  Automatically accounts for thresholds for not included channels
- **R-matrix Faddeev approach for three-body breakup channels (H. Leeb)**
  (numerical implementation in progress)
- **Newly added analyzing power for spin 1/2-particles**

Tests and Verification

- **Computable R-matrix comparison with FRESCO:**



Example: (n ^{12}C) scattering with two inelastic excitations

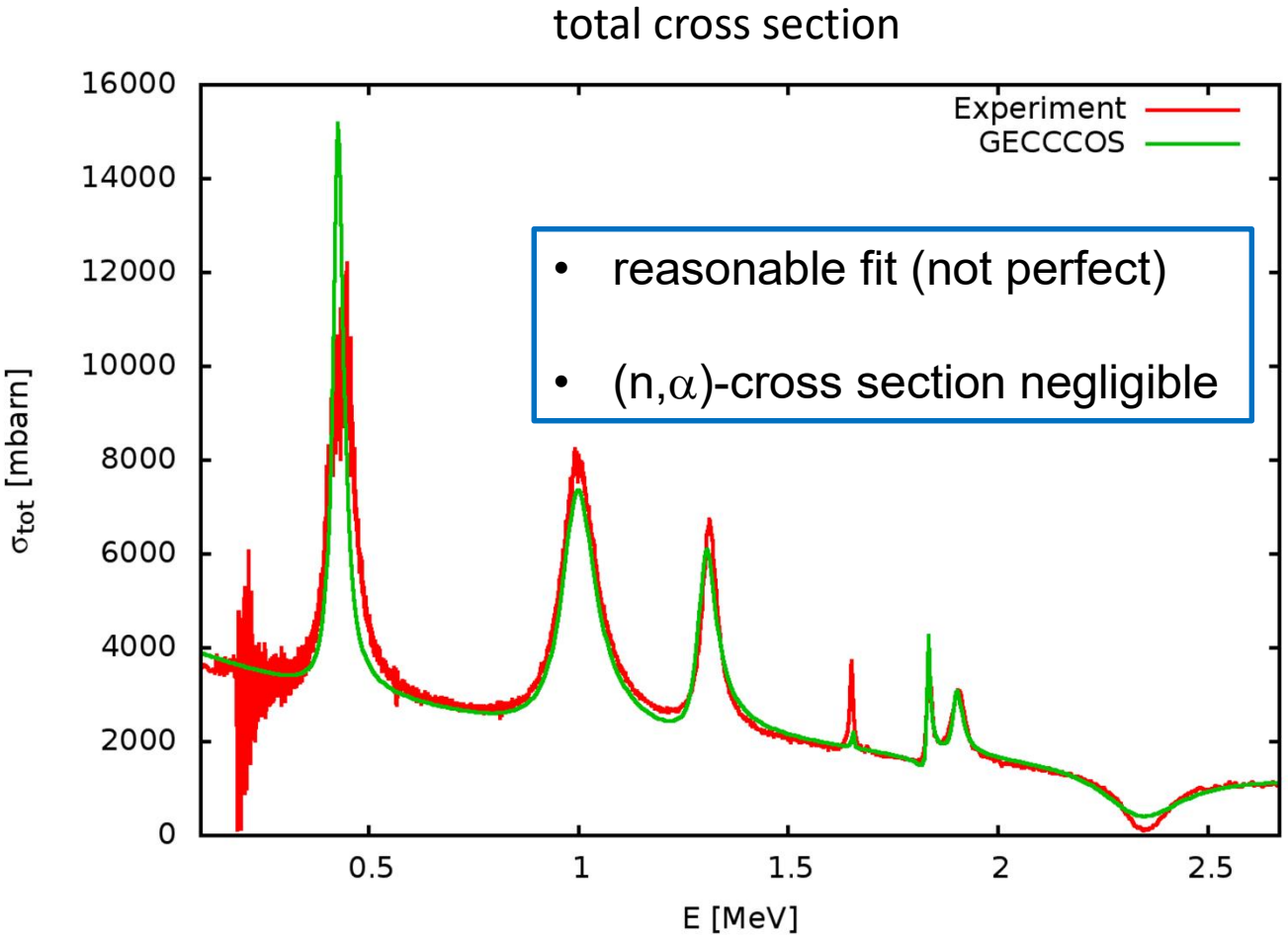
GECCCOS ←→ FRESCO

Consistency archived

- **Phenomenological R-matrix implementation verified:**
  participated R-matrix Working group code comparison at IAEA
  for a test case in the resolved resonance region of the ^{7}Be System for charged-particle reactions

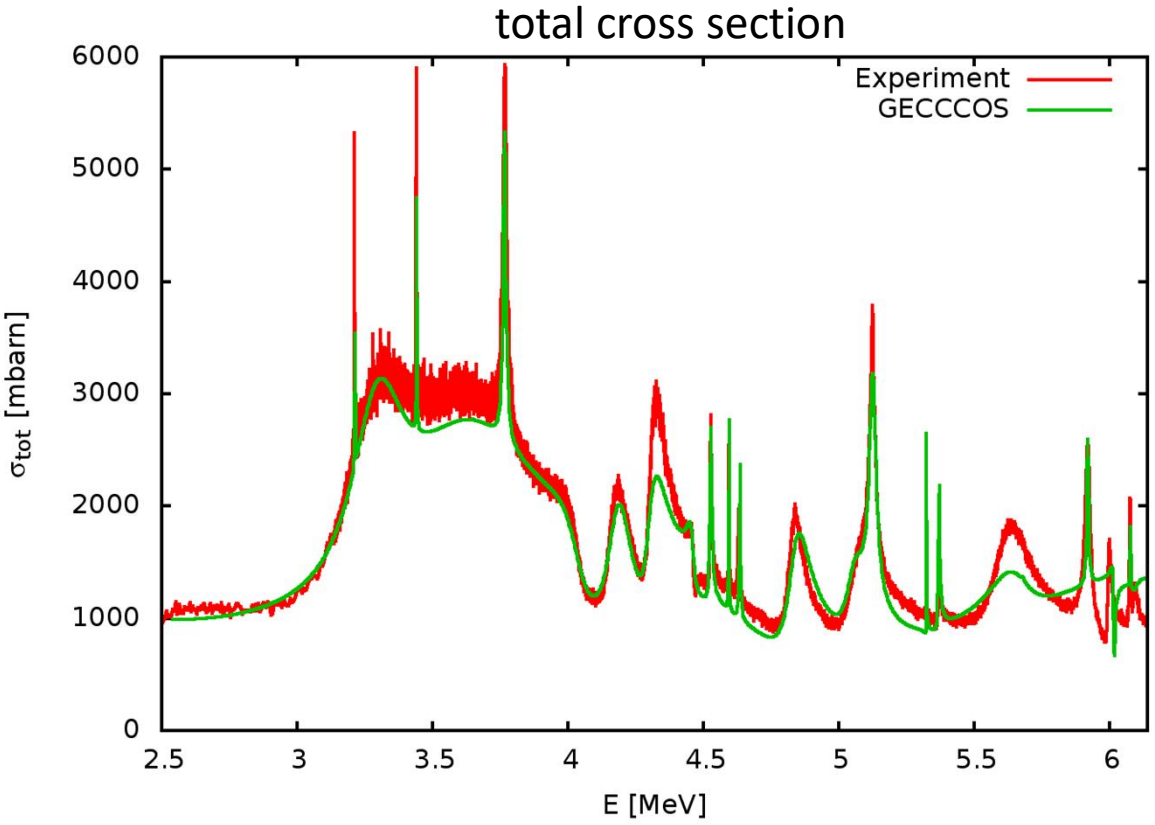
  Published: Eur. Phys. J. A (2019) **55**: 92

(n+^{16}O) at 0.2 – 2.6 MeV

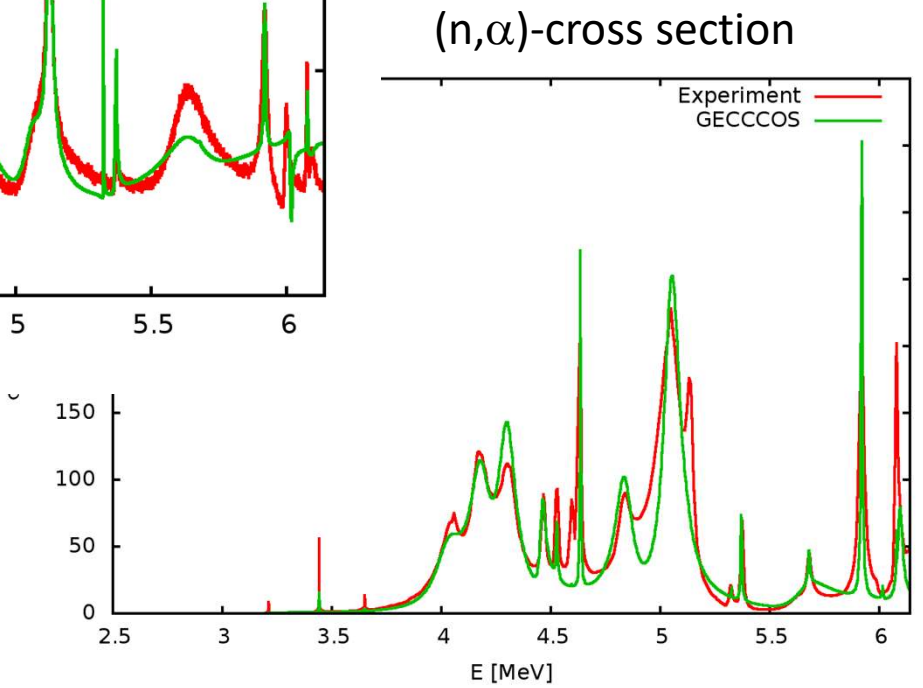


effectively, only elastic channel is contributing

(n,^{16}O) 2.5 – 6.2 MeV



- pole fit (not perfect) done with a=3.27 fm

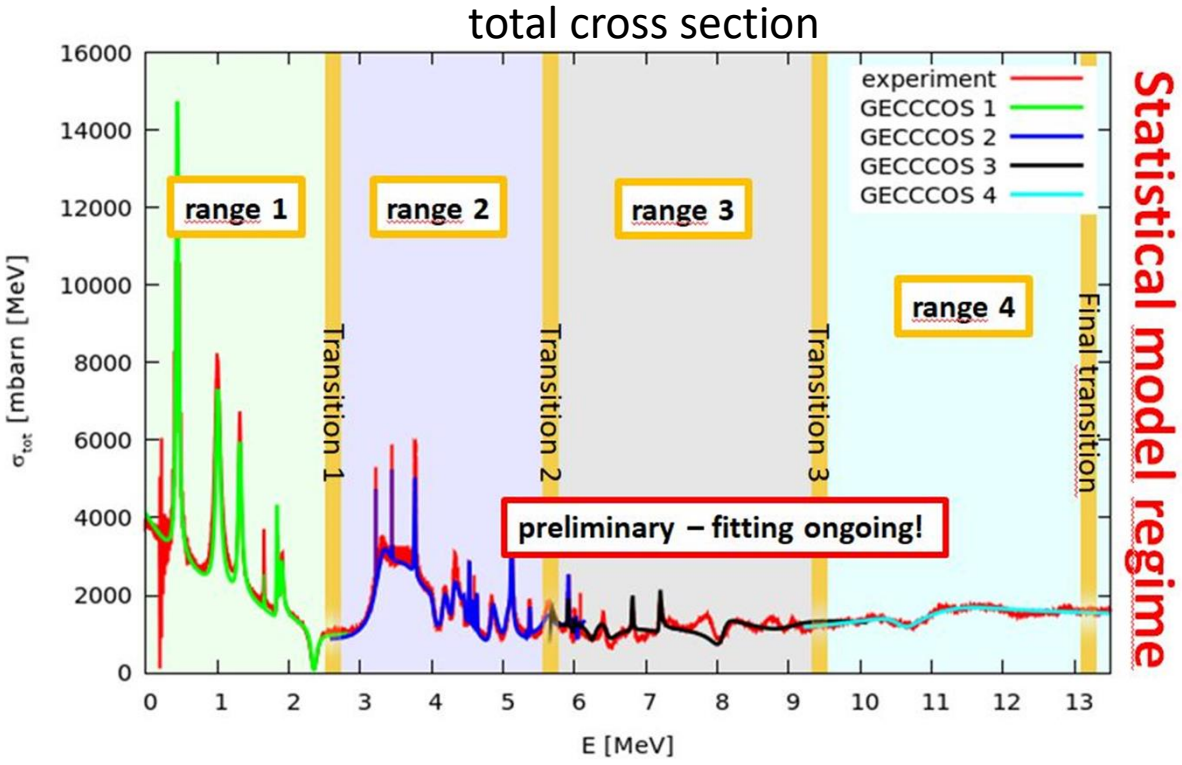


(n,α) reaction channel becomes relevant

(n+^{16}O) at 0.2 – 13 MeV

Towards Statistical Model:

Idea: splitting energy and combining parameter fits



Many channels opening at higher energies

→ increasing number of parameters

→ challenging fitting process

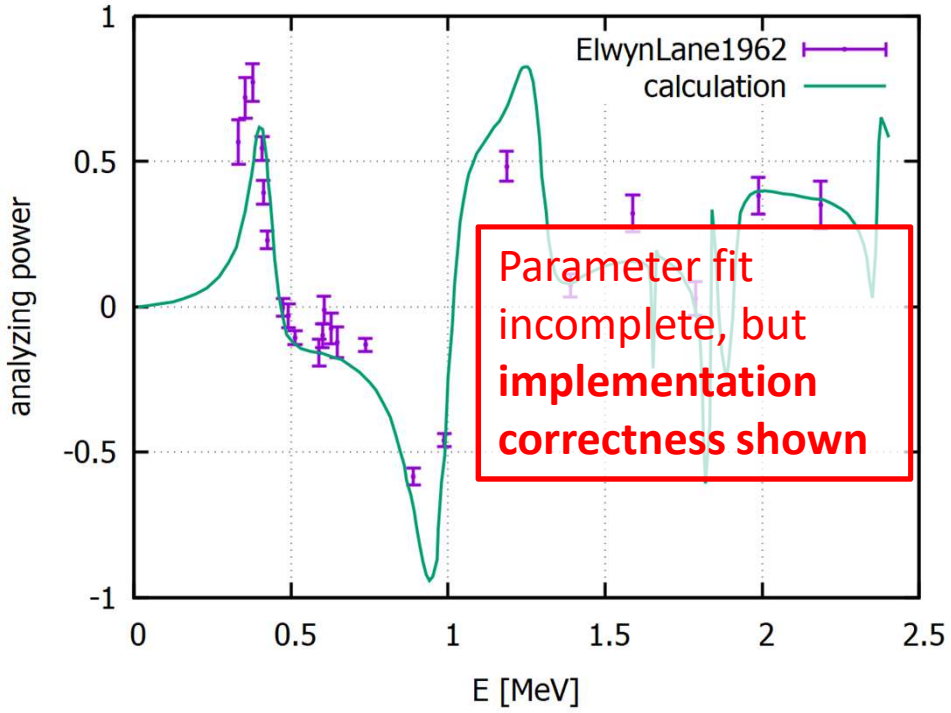
Recent feature update

Polarization Observables:

- **Analyzing power for spin 1/2-particles implemented**
  Student M. Edthofer (Bachelorthesis)

- **Example:**
  comparison with experimental data for $n+^{16}O$

  Data via Exfor:
  A.J. Elwyn, R.O. Lane
  Nucl. Phys., Vol.31, p.78 (1962)



Summary

- GECCCOS successfully used as flexible codebase for R-matrix based calculations
- Correctness of implementation successfully verified against different, well established codes
- Implemented a hybrid, pseudo-potential based R-matrix approach
- Studied behavior of R-matrix under matching radius transformation
- Implemented a Reduced R-matrix approach, which inherently accounts for channel thresholds (Tanja Stary)

Outlook

Module developments

- Streamlining the parameter fitting process for nuclear data evaluation
- Implementing the R-matrix Faddeev method for three-body channels (in progress)

Code development:

- Optimizing code efficiency
- Extending documentation to a full manual
- Automate build process for different platforms (Docker, CMAKE) attach a BuildServer for continuous integration (e.g. Jenkins)
- Grapical User Interface

Thank you for your attention